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was shorter by one-half than the brown, was that the former represented the slower growth by night, and the latter the quicker growth by day—the white and the brown together representing an entire day of twenty-four hours. But other observations by myself have given, as the average growth of the hair of the head in persons who had been shaved, $\frac{1}{8}$ of an inch for the week, and consequently $\frac{1}{56}$ of an inch for the twenty-four hours. Now the length of hair comprehended by the white and the brown in the present case is $\frac{1}{36}$ of an inch, and consequently a much more active growth than is normally met with—corresponding, in fact, in a similar ratio, with thirty-seven hours instead of twenty-four.

I therefore refrain from speculating upon the cause of alternation of the healthy and morbid structure presented by this case, and restrict myself to the narration of the fact that during a certain space of time, amounting to a day or more, the hair is produced of normal structure, while during another space of time of undetermined extent the hair is produced unhealthily,—that the periods of healthy formation correspond pretty accurately in extent, as do those of unhealthy formation, while the latter, in measurement, are only half as extensive as the former,—moreover, that the differences of the pathological operation are, the production of a horny plasma in the normal process, and of serous and watery cell-contents in the abnormal process.

I may further observe that it is by no means improbable that the "dead" and faded hair which is met with after some illnesses and in instances of debilitated health may be due to a similar pathological process, although wanting in the periodicity and alternation which render the present case so remarkable.

III. "Remarks on the Nature of Electric Energy, and on the Means by which it is transmitted." By Charles Brooke, M.A., F.R.S., P.M.S., &c. Received March 19, 1867.

The writer has clearly shown the interchange of thermic and dynamic energy at the point of junction of the bars of a thermo-electric element of antimony and bismuth*, and he has also pointed out† that the dynamic nature of electric energy is not less clearly indicated by the long-known fact that an ordinary voltaic current always commences with a rush, as it were, the instant that the circuit is closed. The dynamic cause of this is clearly pointed out by an experiment due to the genius of Prof. Wheatstone. If a tuning-fork, the tail of which is inserted longitudinally into a wooden handle, like a file or chisel, be made to vibrate, and the end of the handle rested obliquely on a table, the resonance of the table will instantly be heard; but on moving the diapason parallel to itself in any

* Phil. Mag. Nov. 1866. † Ibid. Dec. 1866.

direction on the table, the resonance ceases, from the perpetual interference of the successive planes of vibration with each other. But now comes the illustration:—On arresting the motion of translation, the resonance immediately recommences, but with a rush or momentary increase of sound: this must unquestionably arise from the resistance offered by the inertia of the molecules of wood to the recommencement of wave-motion; and the parallel phenomenon in electricity may undoubtedly be similarly accounted for. And the reflex momentary current (the terminal extra-current of Faraday), which is well known to take place at the instant of opening the circuit, is equally susceptible of a dynamic interpretation: it is the analogue of the wave reflected from the fixed end of a stretched cord, after having been imparted by the hand to the free end.

The dynamic nature of electric energy is clearly indicated by the dynamo-electric* machine of Holtz, in which dynamic is directly converted into electric energy,—and by the cognate machines of Wilde, Wheatstone, Siemens, and Ladd, in all of which alike there is an intervening conversion of dynamic into magnetic energy. The enormous amount of current-energy evolved in Mr. Wilde's machine when the power of a steam-engine is employed to rotate the armatures may be judged of by the fact that a long piece of platinum wire 0·2 inch in thickness was seen to be disintegrated and partially fused. It is difficult to conceive that in these instances dynamic energy can be converted into magnetic "fluid," and that again into thermic energy: the conversion of motion into matter, and the subsequent reconversion of matter into motion, are obviously impossible.

Some further consideration of the effects of electric energy may serve to indicate the probable nature of the wave-motion. The facts of electric and magnetic polarity imply and necessitate a polarity or directionality in the motion itself, which has no analogue in the waves of sound, light, or heat. This requirement is fully met by the hypothesis of a circular spiral wave, the motion of which is direct or positive if viewed from one end, and retrograde or negative if from the other; and this suffices to explain the well-known polarity of electric and magnetic induction.

Thus far the spiral hypothesis is merely inferential; but in regard to magnetic wave-motion some strong presumptive evidence may be adduced. It appears from the experiments of Mr. Joule, made more than twenty years ago, that if a suspended mass of copper be, by twisting the suspension, made to rotate between the poles of an unexcited electro-magnet, the

* The writer has elsewhere applied (Elements of Natural Philosophy, p. 550, *note*) a definite and intelligible meaning to the construction of those compound terms which must be constantly employed in relation to the conversions of energy. This may be accomplished by taking the first section of the term to mean the *acting cause*, the second, the *resulting effect*: thus a dynamo-electric machine will be one in which dynamic energy is employed to produce an electric current; and an electro-dynamic engine, one in which a current is employed to evolve dynamic energy.

rotation of the mass is arrested the instant the magnet is excited; and furthermore, if the mass be forcibly rotated, heat is developed in it. And it has since been ascertained that if two cylindrical magnets be so placed that their axes lie in the same straight line, their contrary poles being opposed to each other, then, if a cylinder of copper be made to rotate on its own axis, coinciding with the common axis of the magnets, no heat will be evolved by its rotation.

Now these phenomena must alike be the necessary consequences of the assumed dynamical theory; for if the copper molecules be thrown into spiral-wave motion, analogous to that of a pencil of circularly polarized light, then the motion of all the disturbed particles will be one of revolution in planes to which the lines of magnetic force are normals: and the inertia or energy of rotation (as it has been variously termed), the resistance offered by each revolving particle to any change in the direction of its axis of revolution (as exemplified by the gyroscope), will resist the rotation of the mass in any direction perpendicular to that of the axes of molecular revolution, and arrest its motion. And conversely, if the mass be forcibly rotated in the above direction, or in any other direction at right angles to the lines of magnetic force, heat will be freely developed, doubtless by internal friction arising from the perpetual displacement of the planes of molecular revolution. But in the second case, the axis of rotation of the mass coincides in direction with those of the axes of molecular revolution; hence there is no displacement of the molecular orbits, and consequently no internal friction, and very little if any heat is generated.

The rotatory character of the magnetic wave is further confirmed by the known fact that, if a plane-polarized beam pass through a transparent solid in the direction of the lines of force of a powerful electro-magnet, the plane of polarization will be rotated the instant that the magnet is excited. The truth of a theory can be established only by the verification of its necessary consequences; and it may not be too much to assume that in the present case the evidence already adduced by the writer is, in the entire absence of all contradictory evidence, strongly presumptive of the reality of the hypothesis.

It has been authoritatively stated that ordinary electric and magnetic waves *cannot both* be assumed to be spirals, because each of these forms of energy notoriously evolves the other in a direction perpendicular to its course; and the question is not without grave dynamical difficulties; but they may perhaps not be insuperable. It may possibly be that, from some unknown constraining condition or property inherent in magnetic bodies, a spiral wave, on being constrained into a spiral course, may lose its original spirality, and become a secondary spiral, having molecular motion in a direction perpendicular to that of the primary spiral.

The relations between electric energy and some of its observed physical results having thus been inferred, the question next arises as to the nature

of the media by which the several modes of motion are transmitted. It is unquestionable that sound-waves are transmissible by all kinds of matter; but can any valid reason be assigned in favour of the still prevalent opinion that other modes of wave-motion are incapable of transmission by ordinary matter?—this incapacity being implied in the adoption of the self-contradictory hypothesis of an imaginary medium, not cognizable by any known means of perception.

It is a remarkable fact that in all the superseded crude notions of physical causation, each phase of physical energy has been presented in the garb either of impalpable, imponderable (in fact *immaterial*) matter itself, or of the vibrations thereof; and to some of these hypotheses have been successively added some violent supplementary hypothesis, in order adequately to meet the requirements of advancing knowledge.

To begin with chemical action:—What are now universally recognized as simple metals were once supposed to consist of some earthy matter (their oxides) combined with "Phlogiston,"—the *material* principle of brilliancy. But, unfortunately for the theory, it was soon found that the metals, on parting with their share of phlogiston (*i.e.* becoming oxidated), not only did not *lose* any, but actually *acquired* weight; therefore phlogiston was assumed to be not only *imponderable,* but *hyper*-imponderable—*i. e.* endowed with the property of absolute levity, or negative weight!

In the next place, the Newtonian theory of light assumed light to consist of molecules (of course *imponderable*) emanating from the source of light, and impinging on the perceptive organs of vision. But this hypothesis would not fit the phenomena of diffraction and interference; and to suit these physical facts the molecules must either be thrown into periodical "fits" of transmission or reflection, or the ray must be a row of egg-shaped molecules perpetually making isoperiodic somersaults, and plunging into a medium if they come on their heads, or bounding off if they fall against it sideways. Then, again, heat was supposed to consist of material particles emanating from the source of heat; and as a ball of ice placed in one focus of a concave mirror was found to lower the temperature of a thermometer placed in the conjugate focus, there were assumed to be particles of *cold,* as well as of *heat*: it is needless to add how completely the theory of exchanges accounts for these facts. At length these wild speculations were superseded, and light and heat were admitted into the category of wave-motion; but electricity and magnetism were still supposed to be either single or dual forms of "fluid" matter; and

("Saxa etiam molli dura teruntur aquâ")

these "fluids" are probably still running in the deep channels they have worn in some philosophic minds.

But the principle of admitting imponderability into the category of legitimate physical hypotheses had become tacitly accepted; and the conclusion was at once jumped at by the authors of the undulatory theory

that the wave-motions of light and heat take place in an *imponderable* highly elastic fluid medium, pervading all space, *and all matter*, denominated "æther:" and this theory, with all its inconsistencies and inconsequences, is still in all probability generally entertained.

That some highly elastic and attenuated medium pervades infinite space, as the medium of transmission of the energies of light and heat (the very main-springs of organic existence) from the centre of each solar system to its dependent satellites, is a necessary consequence of the undulatory theory: its existence is, in fact, demonstrated by the periodic retardation of Encke's Comet. But the *remainder* of the hypothesis, namely that all palpable matter is pervaded by æther for the purpose of transmitting light- and heat-waves, is by no means equally necessary, or even tenable; for not a shadow of evidence of the inadequacy of all matter to transmit these motions has ever been produced, and in default of such evidence, the contrary hypothesis is at least equally tenable: and moreover the *interstitial-æther* theory (in common with all preceding physical theories involving imponderability) is burdened with grave inconsistencies. In the first place the well-known phenomena of single and double refraction and polarization, whether of light or heat, necessitate the somewhat violent hypothesis that the elasticity of the supposed transmitting medium, æther, is not, as it is in all cognizable fluids, a fixed and certain quality capable of numerical estimation, but an ever-varying quality, depending quantitatively on the elasticity of adjacent matter, and even varying in *two* or *three* directions within the same body: it would be not more repugnant to reason to assume that the elasticity of a gas is one thing in a glass bottle and another in one of brass, or that the specific gravity of silver is a function of the moon's age, or the melting-point of gold dependent on the sun's zenith-distance. Secondly, the fundamental ideas of inertia, energy, and "work" are inseparably associated with gravitation; and it seems to imply a contradiction of terms, to impute either inertia or energy (*i.e.* the capability of doing work) to an *imponderable* particle, which is consequently destitute of attraction for any other particle in the universe.

The known enormous velocity (of probably not less than 250,000 miles in a second) at which electricity travels through a copper conductor is complete evidence that ordinary matter is capable of transmitting *something* (whether matter or motion it signifies nothing for the present argument) at a considerably greater velocity than the waves of light and heat; why should not appropriate kinds of matter be assumed capable of transmitting these also? And if so, the need of the interstitial presence of æther ceases altogether; and it may with great advantage be excluded from the domains of ponderable palpable matter by the very mild hypothesis that it is *not miscible* with air, any more than oil, or *palpable* ether, with water, but that it floats above the boundary surface of our atmosphere. This hypothesis is not repugnant to reason, nor adverse to physical experience. On this supposition it is no longer needed to impute to æther

imponderability; it will then be competent to fulfil its divine mission of transmitting light and heat, without doing any violence to some of the most fundamental notions of dynamics; and thus imponderability may cease to be reckoned amongst the physical attributes of matter.

March 28, 1867.

Lieut.-General SABINE, President, in the Chair.

The following communications were read:—

I. "A Comparison between some of the simultaneous Records of the Barographs at Oxford and at Kew." By BALFOUR STEWART, LL.D., F.R.S., Superintendent of the Kew Observatory. Received March 4, 1867.

Through the kindness of the Rev. Robert Main, director of the Radcliffe Observatory, Oxford, certain marked features of the curves produced by the barographs at Oxford and at Kew were compared together on four separate occasions in the year 1863.

These comparisons are the more interesting that they were all made during squalls or storms; for on such occasions it is found that the barograph curves exhibiting the height of the barometer from moment to moment present curious characteristic points, without which indeed no such comparisons could be made.

The result for these four occasions in 1863 was as follows:—

Nature of disturbance.	Date G. M. T. Oxford.	Kew.	Oxford is before Kew.
Sudden increase of pressure during squall of 30th October 1863	2.30 P.M.	3.9 P.M.?	39 minutes (probably).
Sudden increase of pressure during squall of 21st November 1863	4.0 P.M.	4.45 P.M.	45 minutes.
Peculiar points in the curves of December 3, 1863 (a stormy day)	2.40 A.M.	3.35 A.M.	55 minutes.
	6.50 A.M.	7.40 A.M.	50 minutes.

Mr. Main has kindly called my attention to a well-marked minimum in the Oxford curve for February 6, 1867, which was also a stormy day. This minimum occurred at Oxford at 2.20 A.M. of that day, while at Kew it did not occur until 3.15 A.M. Oxford was thus on this occasion 55 minutes before Kew.

The peculiarity of this last occasion is the singular likeness between the two curves. I have not compared together any other features of these curves, nor perhaps could this be done with exactness; but the general